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(54) Abstract Title  
**Monitoring radio signals for handover in a mobile station**

(57) A mobile station operating in FDD (frequency division duplex) mode switches to TDD (time division duplex) mode in order to monitor signals from neighbouring base stations or communications systems. The mobile can then perform handover in TDD mode to the alternative base station or system. The mobile station may be a UMTS (universal mobile telecommunication standard) mobile phone with TDD and FDD modes of operation. Switching to TDD mode before handover avoids the need to create idle periods using a compressed mode of operation in FDD mode for monitor signals. Inter-system handover may be to GSM system.

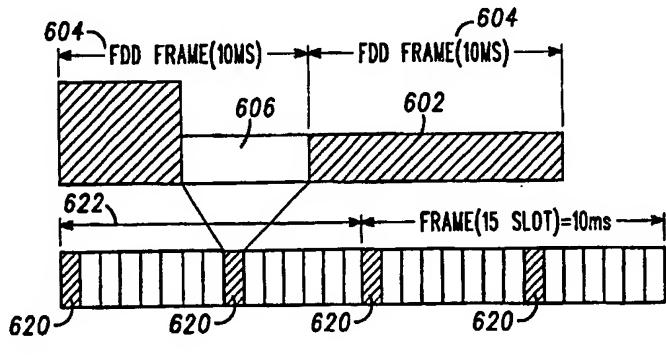


FIG. 6

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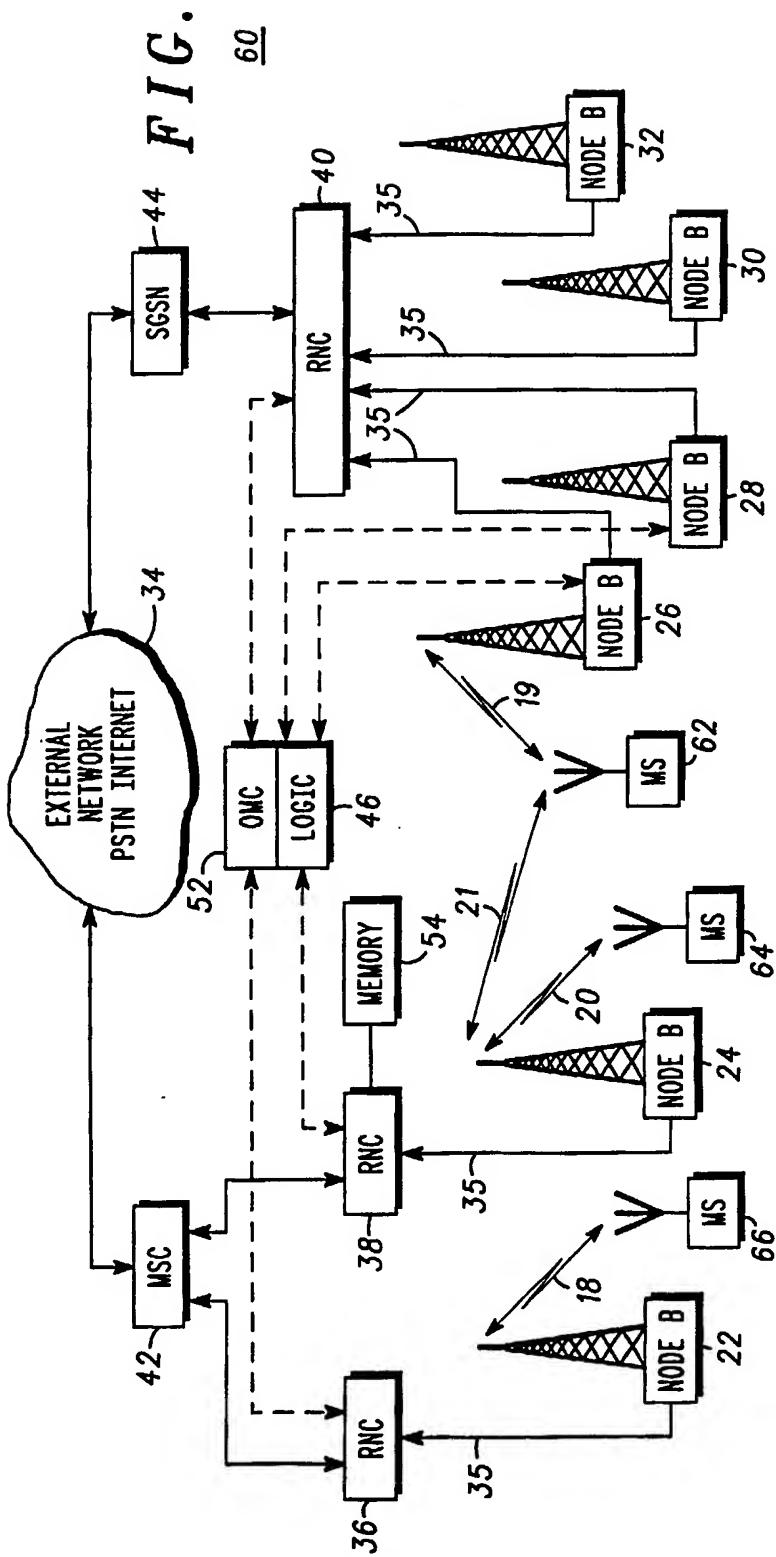
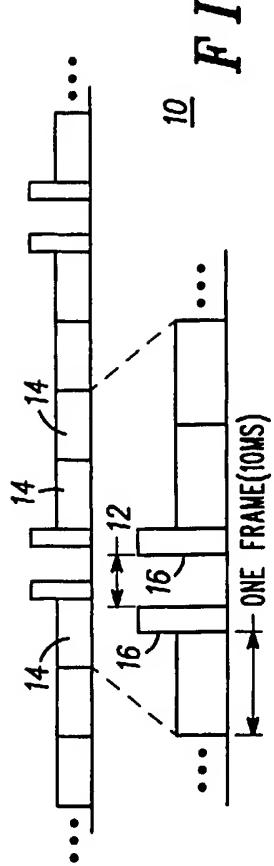


FIG. 1



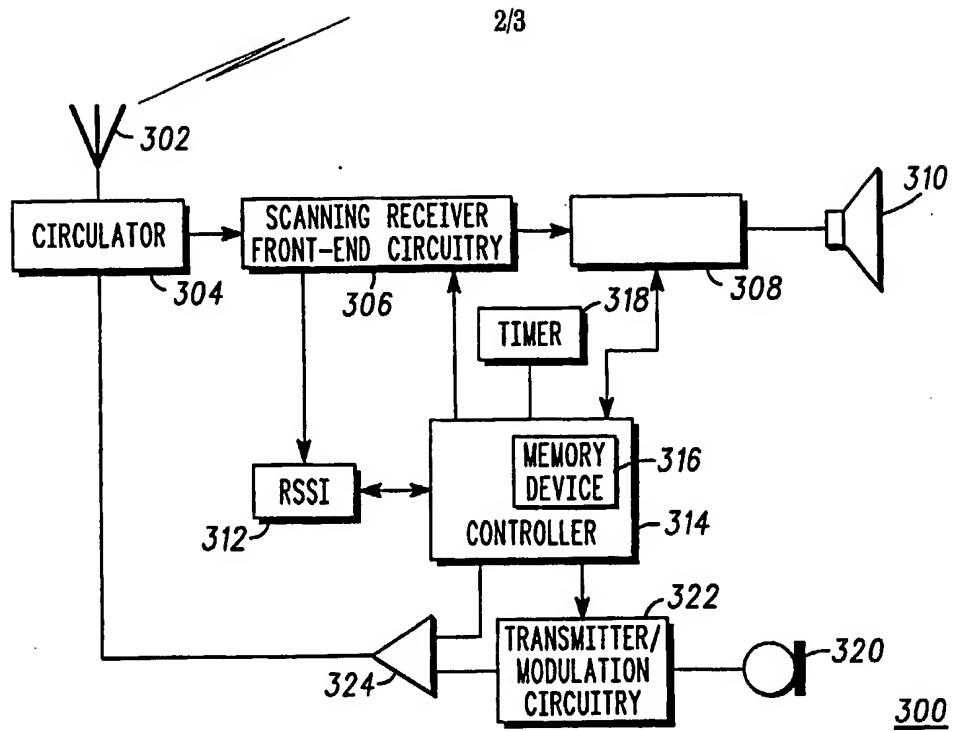


FIG. 3

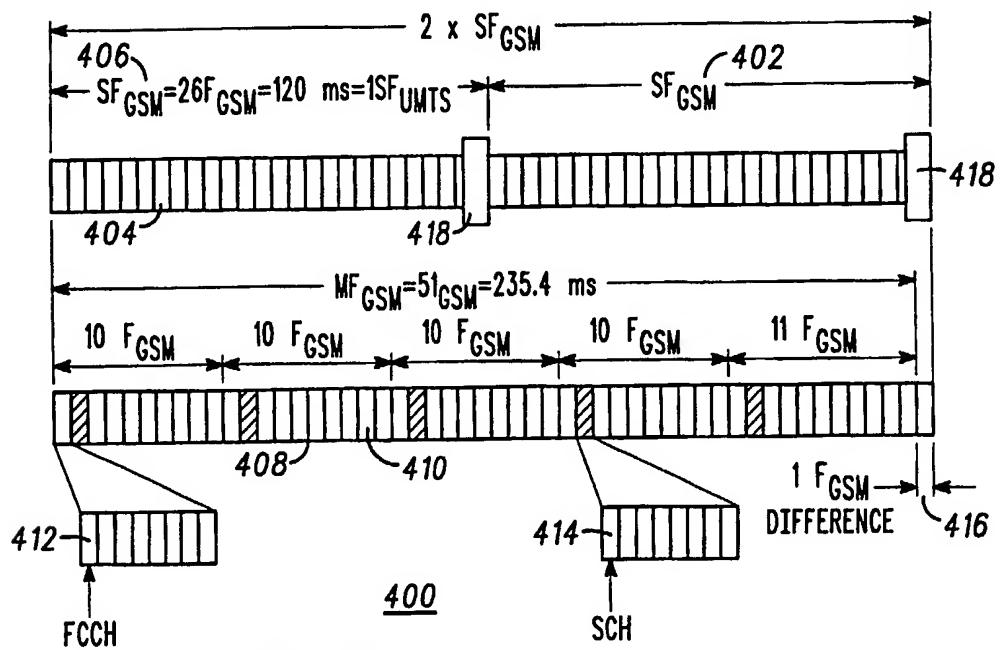
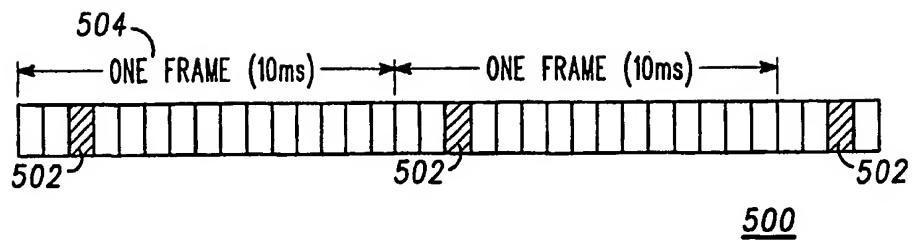
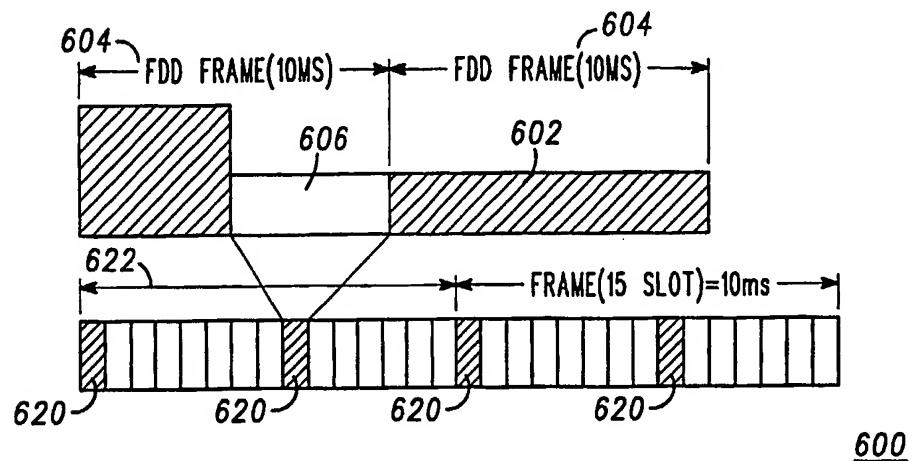


FIG. 4

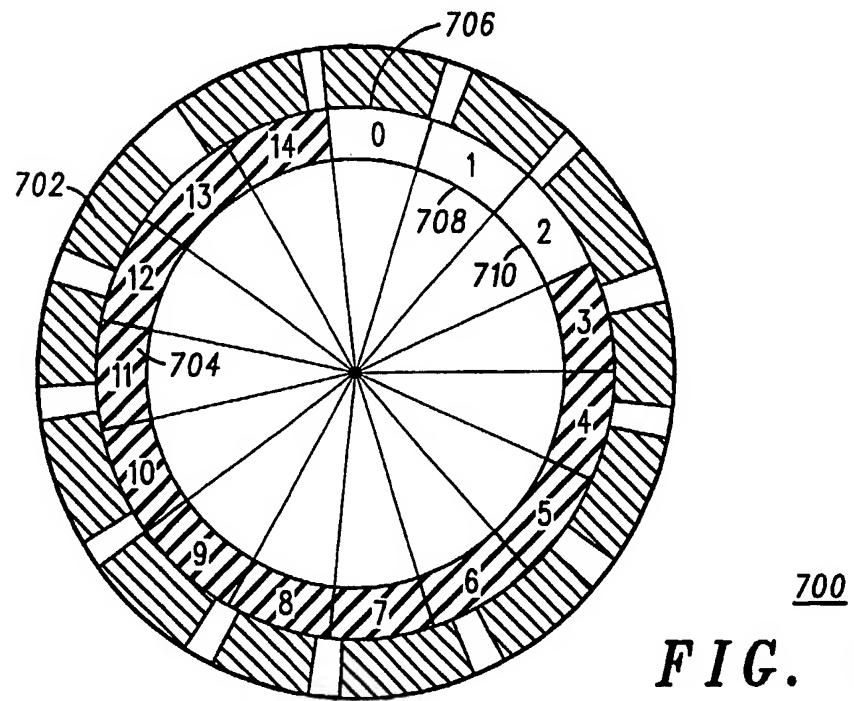
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**FIG. 5**



**FIG. 6**



**FIG. 7**

COMMUNICATION SYSTEM, COMMUNICATION UNIT AND METHOD OF  
OPERATION

5 **Field of the Invention**

This invention relates to the measurement of signals in communication systems. The invention is applicable to, but not limited to, the measurement of signals in adjacent or alternative communication systems by performing a measuring process in a Time Division Duplex (TDD) mode of the Universal Mobile Telecommunication Standard (UMTS), whilst primarily operating in a compressed Frequency Division Duplex (FDD) WCDMA mode.

15

**Background of the Invention**

Wireless communication systems, for example cellular telephony or private mobile radio communication systems, typically provide for radio telecommunication links to be arranged between a plurality of base transceiver stations (BTSs) and a plurality of subscriber units, often termed mobile stations (MSs).

25

Wireless communication systems are distinguished over fixed communication systems, such as the public switched telephone network (PSTN), principally in that mobile stations move between BTS (and/or different service providers) and in doing so encounter varying radio propagation environments.

Methods of communicating information simultaneously exist where communication resources in a communication network are shared by a number of users. Such methods are termed 5 multiple access techniques. A number of multiple access techniques exist, whereby a finite communication resource is divided into any number of physical parameters, such as:

- (i) frequency division multiple access (FDMA)  
10 whereby the total number of frequencies used in the communication system are shared,
- (ii) time division multiple access (TDMA) whereby each communication resource, say a frequency used in the communication system, is shared amongst users by dividing 15 the resource into a number of distinct time periods (time-slots, frames, etc.), and
- (iii) code division multiple access (CDMA) whereby communication is performed by using all of the respective frequencies, in all of the time periods, and the resource 20 is shared by allocating each communication a particular code, to differentiate desired signals from undesired signals.

Within such multiple access techniques, different duplex 25 (two-way communication) paths are arranged. Such paths can be arranged in a frequency division duplex (FDD) configuration, whereby a frequency is dedicated for uplink communication and a second frequency is dedicated for downlink communication. Alternatively, the paths can 30 be arranged in a time division duplex (TDD) configuration, whereby a time period is dedicated for

uplink communication and a second time period is dedicated for downlink communication.

In a wireless communication system, each BTS has  
5 associated with it a particular geographical coverage area (or cell). The coverage area is defined by a particular range where the BTS can maintain acceptable communications with MSs operating within its serving cell. Often these cells combine to produce an extensive  
10 coverage area.

The communication link from the BTS to a MS is referred to as the down-link. Conversely, the communication link from a MS to the BTS is referred to as the up-link.

15 Present day communications systems, both wireless and wire-line, have a requirement to transfer data between communications units. Data, in this context, includes speech communication. Such data transfer needs to be  
20 effectively and efficiently provided for, in order to optimise use of limited communication resources.

In the field of this invention, it is known that in the planned Universal Mobile Telecommunications Standard  
25 (UMTS) each cell site (a local collection of BTS), and correspondingly each base station controller (BSC) co-ordinating communications for a number of such BTS, will have limited hardware, software and firmware resources. These limitations must be taken into account when  
30 performing admission control of a new radio link. The general term used for cell site in the UMTS arena is a

Node B, with a BSC known as a Radio Network Control (RNC).

In the field of this invention it is known that user's move between locations and therefore, occasionally, between different communication service providers. Such transfer between communication service providers may also occur within a single call. The decision on when to transfer such service provision is difficult, due to radio propagation conditions (user mobility, fluctuations in traffic density, heterogeneity of the environment, etc.) continuously changing and thereby affecting the signal quality of received signals. Such varying propagation conditions apply to received signals from both the user's serving cell as well as the intended serving cell.

Clearly, measurement of the communication environment is an extremely important procedure in designing and operating such cell-based communication systems, where mobile stations (MSs), often termed mobile terminals (MTs) need to perform measurements both in connected (in call) and non-connected (scanning) modes.

In connected mode, measurements help to continuously identify the strongest pilots/signals received from neighbouring BTS or Node B's. Comparing measured signals from neighbouring BTS with signals from the current serving cell's pilot strength, a determination on whether to initiate a handover procedure may be initiated. Such determination can be made by the MS, the MS-initiated

hand-over being termed Mobile Assisted Hand-over (MAHO), or by the serving BTS using MS reported measurements, termed Network Assisted Hand-over (NAHO).

- 5 In non-connected mode, MSs make regular measurements of all cells within its communication range to determine which is the most appropriate cell to serve the MS, when the MS wishes to enter into a communication.
- 10 Procedures to make measurements for each deployed cellular system such as GSM, GPRS, IS-95, IS-136, are described in GSM 05.08, European Telecommunications Standards Institute (ETSI); Mouly M. and Pautet M.B., "The GSM System for Mobile Communications", Palaiseau, France (1992) and Goodman D. J., "Wireless Personal Communications systems", Addison-Wesley, 1997.
- 15 Furthermore, in the preferred embodiment of the invention, such measurement procedures are currently being specified for 3<sup>rd</sup> Generation cellular systems such as UMTS.

- 20 As the radio environment is already very heterogeneous with a tendency to diversify further, there is a need to inter-operate the systems and make handover seamless to the users. Both intra-system and inter-system handovers will be employed to cope with users' mobility and maximise the efficiency of communications within the system. Inter-system handovers will be necessary either due to coverage or due to a joint radio resource management policy co-ordinating the systems involved in handover.

In the context of the preferred embodiment of the invention, an example of such an inter-system handover is between UMTS and GSM, where both UMTS FDD to GSM and UMTS 5 TDD to GSM are currently being specified in the UMTS standard.

A number of factors will dictate the mechanics in a UMTS to GSM handover, such as:

- 10 (i) Coverage: the GSM coverage (per cell) is larger than the coverage being proposed for UMTS (per cell);
  - (ii) Capacity: by balancing voice (or data) users between UMTS and GSM, to maximise use of the communication resource, as the UMTS system will be able 15 to operate at higher bit-rates; and
    - (iii) Radio Conditions: If radio conditions deteriorate in, say, a UMTS system, in order to meet the Bit Error Rate (BER) target of the ongoing high bit-rate services, some voice (or data) users may need to be 20 handed over to an appropriate GSM system.

Consequently, such co-existing systems need to cooperate and MSs need to be able to perform measurements on all possible serving systems. The ability, and moreover 25 processing time, to perform such measurements is critical in present state of the art MSs, which are heavily software-based, such as the Software Definable Radio (SDR). Here, depending upon the time and processing requirements of say, Real Time (RT) applications, the 30 time dedicated to measurements may be significantly impacted.

In order to listen to transmissions from any alternative system or cell, for example GSM carriers, in preparation for a hand-over operation, one option could be to equip 5 each communication unit with a dual receiver. In such a scenario, the dual-receiver would operate in both the current serving cell and monitor transmissions from the proposed serving cell or system. However, the UMTS standard defining body has already rejected a dual-10 receiver approach in favour of a compressed mode of operation due to cost.

In UMTS/FDD mode the transmission is normally continuous. Hence, the only mechanism available to MSs to monitor 15 transmissions from alternative cells or systems requires the MS to move to a "compressed mode" of operation. In the context of the preferred embodiment of the invention, the UMTS MS will enter a compressed mode of operation to be able to listen to an alternative GSM carrier.

20 Referring now to FIG. 1, the prior art principle of compressed mode 10 is shown. The aim of operating in compressed mode is to interrupt the FDD continuous transmission by creating idle periods without affecting 25 the ordinary data flow. Four time periods are shown, with time periods 1, 3 and 4, referenced as 14, shown in normal operation. The second time period is shown with an idle period created in its centre 12.

30 In order to create such an idle period, the information 16 that was to be transmitted during this period is sent

at twice the rate (twice the power), for half the time, thereby creating a period where neighbouring cell or system scanning can be performed. When the information is compressed, more interference is visibly created as  
5 the BS increased the power during this period.

However, operating in Compressed mode suffers from many drawbacks. In particular, the present proposal in UMTS to transition from a UMTS FDD mode of operation to, for  
10 example, a GSM mode of operation is to use compressed mode.

In using compressed mode in FDD, a dual mode GSM/UMTS-FDD MS must be capable of FCCH detection within 11  
15 consecutive patterns of 6 msec slots at 120 msec spacing.

Therefore, a minimum transition period of 1.32 seconds is required in the current proposed procedure. As several GSM carriers need to be detected and measured, the  
20 procedure is time and processor intensive, for example in order to detect 6 GSM carriers, 66 idle periods of 6 msec (at 120 msec spacing) may be needed.

Whilst operating in compressed mode in a CDMA system, the  
25 following problems are encountered:

(i) either the CDMA spreading factor is divided by two and the service rate is multiplied by two. As a consequence, the system interference is inherently  
30 increased during the compressed mode period and this factor is more problematic than any resultant code

shortage. Indeed, in heavy loaded conditions, the primary cause of communication outage is due to interference, such as the increased interference generated by MSs entering a compressed mode, rather than 5 code shortage; or

(ii) the coding rate is decreased, which naturally degrades the BER performance; or

10 (iii) Discontinuous Transmission (DTX) is needed which is inherently service dependent.

The three techniques mentioned above, all have a similar objective, namely to introduce silence periods in the 15 continuous transmission without disturbing the overall data flow.

Compressed mode also causes severe problems to any system operating power control loops. Furthermore, compressed 20 mode is not very suitable when system resources are excessively utilised close to an instability region.

When designing CDMA systems the provision of cells has to be arranged such that the infrastructure is over- 25 dimensioned, to avoid any possibility of operating in such instability regions.

Clearly, in attempting to measure the service provision of alternative systems for inter-system hand-over, or 30 alternative cells in the same system for intra-cell hand-over, compressed mode is required due to the need to

create a series of time-periods in which to make possible measurements.

5 Thus there exists a need in the field of the present invention to provide a communication system, a communication unit, a method of monitoring signal transmissions and a method of hand-over of a communication wherein the abovementioned disadvantages  
10 may be alleviated.

**Statement of Invention**

15 In accordance with the present invention there is provided a communication system, as claimed in claim 1.

In accordance with the present invention there is provided a communication unit, as claimed in claim 9.

20 In accordance with the present invention there is provided a method of monitoring signal transmissions in a wireless communication system, as claimed in claim 10.

25 In accordance with the present invention there is provided a method of hand-over of a communication, as claimed in claim 11.

**30 Brief Description of the Drawings**

A communication system, a communication unit, a method of monitoring signal transmissions and a method of hand-over incorporating the present invention will now be described, by way of example only, with reference to the 5 accompanying drawings, in which:

FIG. 1 shows a timing diagram of a FDD compressed mode of operation, in accordance with the known prior art.

10 FIG. 2 shows a block diagram of a cellular radio communications system adapted to support the various inventive concepts of a preferred embodiment of the present invention.

15 FIG. 3 shows a block diagram of a cellular radio communications unit adapted to support the various inventive concepts of a preferred embodiment of the present invention.

20 FIG. 4 shows a timing diagram of a TDD transmission mode of operation, in accordance with a preferred embodiment of the present invention.

FIG. 5 shows a timing diagram of a GSM super-frame, GSM  
25 multi-frame and UMTS super-frame structures, in accordance with a preferred embodiment of the present invention.

30 FIG. 6 shows a timing diagram of a TDD Synchronisation Channel(SCH) for TDD detection from a FDD (compressed)

mode of operation, in accordance with a preferred embodiment of the present invention.

FIG. 7 shows an example of the distribution of a MS  
5 operating in a FCCH GSM slot and in a TDD slot, in accordance with a preferred embodiment of the present invention.

#### 10 **Description of Preferred Embodiments**

- In summary, the inventive concepts of the present invention include a mechanism for increasing measurement speed, equivalent to a reduction in measurement time, of  
15 signal transmissions from other communication systems (for example GSM, IS-95). Such alternative system measurements are to be made whilst normal operation continues in UMTS FDD by switching into a UMTS TDD mode.
- 20 In particular, UMTS FDD and UMTS TDD modes are jointly deployed to avoid, or at least limit, the frequency of MSs using a "compressed mode" to perform such alternative system measurements.
- 25 The inventors have recognised that TDD has the advantage of a time-slotted structure that makes the well-established compressed mode unnecessary. Hence, in performing a hand-over from a UMTS FDD mode to an alternative communication system such as GSM, a MS makes  
30 a double hop FDD to TDD to a non-UMTS system. This is achieved by making measurements in a TDD mode of

operation, which is more efficient than a direct hand-over from a UMTS FDD mode of operation to a non-UMTS system.

- 5 In another embodiment, the idea may be used more generally to prevent utilization of compressed mode for measurement purposes whilst being in FDD. In accordance with an embodiment of the invention, MSs may switch into a TDD mode of operation, as the time needed is relatively  
10 short, to perform measurements in any neighbouring cell or system, before returning back to FDD mode.

It is noteworthy that in TDD a user may be given one or more codes and may transmit in single or multiple time  
15 slots depending on the resource allocation policy in contrast to the mechanism employed in compressed mode. Slots that are not used for transmission can be easily used to listen to other signals.

- 20 Advantageously, switching into a TDD mode of operation also allows more flexibility due to the various application constraints (real-time versus non-real-time, low bit-rate versus high bit-rate). In such a situation,  
25 some slots may be used for normal transmissions whilst some slots may be left available to make measurements.

An example is an application using four time slots per frame for a normal transmission. There are 11 slots left in each frame to prepare and execute measurements.  
30 However, if the service rate is temporarily reduced to

only two slots per frame, up to 13 slots will be left available for measurement purposes.

In this manner, using TDD capabilities to avoid FDD compression mode when measuring GSM or other systems is novel. The proposal applies to any situation where measurements are needed between operating in a FDD mode, for example in a UMTS system, and other non-UMTS systems, such as FDD (UMTS) to GSM, FDD (UMTS) to IS-95, FDD (UMTS) to IS-136.

Referring now to FIG. 2, a cell-based telephone communication system 60 in outline is shown, supporting a Universal Mobile Telecommunications Standard (UMTS) air-interface in accordance with a preferred embodiment of the invention.

A plurality of subscriber units 62-66 communicate over the selected air-interface 18-21 with a plurality of Node Bs - in UMTS terminology - 22-32. A limited number of MSSs 62-66 and Node Bs 22-32 are shown for clarity purposes only.

The Node Bs 22-32 may be connected to external networks, for example, the public-switched telephone network (PSTN) or the Internet, 34 through Radio Network Controller stations (RNC) (in UMTS terminology) 36-40 and any number of mobile switching centres (MSCs) 42 and Serving GPRS Support Nodes (SGSN) 44.

Each Node B 22-32 contains one or more transceiver units and communicates with the rest of the cell-based system infrastructure via the Iub interface 35.

- 5    Each RNC 36-40 may control one or more Node Bs 22-32. Each MSC 42 (only one shown for clarity purposes) provides a gateway to the external network 34, whilst the SGSN 44 links to external packet networks.
- 10   The Operations and Management Centre (OMC) 46 is operably connected to RNCs 36-40 and Node Bs 22-32 (shown only with respect to Node B 26 and Node B 28 for clarity), and administers and manages the parts of the cellular telephone communication system 60, as will be understood by those skilled in the art.
- 15

- 20   In accordance with a preferred embodiment of the present invention, at least one of the Node Bs (a serving communication unit) 22-32, has been adapted to offer, and provide for, a TDD mode of operation instead of a compression mode of operation, when a MS is operating in FDD mode.

- 25   It is within the contemplation of the invention that the switch to a TDD mode of operation may alternatively be controlled in another part of the infrastructure, for example by at least one of the RNCs 36-40 or the OMC 46.

- 30   In the preferred embodiment of the invention, if the system offers MAHO, the Node B either receives a request from a MS to enter into a FDD compression mode of

operation, or if the MS knows that a TDD mode of operation is available, receives such a request, and the Node B informs, and manages the switch to a TDD mode of operation. Such a switch can be effected to assist the 5 hand-over process or allow the MS to perform neighbouring cell or system measurements.

Alternatively, if the system offers NAHO, the Node B, in the preferred embodiment of the invention, initiates a 10 TDD operation, in contrast to initiating a compression mode of operation, in cases where neighbouring cell or system measurements would normally be made.

In one embodiment of the invention, the Node B has also 15 been adapted to inform at least one of its corresponding RNCs 36-40 of such a TDD mode of operation, in cases where a MS would normally be switched to a compression mode of operation, for example to measure the signal strength of neighbouring cells or systems.

20 Note that a corresponding adaptation of the RNC 36-40, or the OMC 46, has been implemented to acknowledge, process and respond to such a switch to TDD mode of operation.

25 Turning now to FIG. 3, there is shown a block diagram of a subscriber unit (MS) 300 adapted to support the inventive concepts of the preferred embodiments of the present invention. The MS 300 contains an antenna 302 30 preferably coupled to a duplex filter or circulator 304

that provides isolation between receive and transmit chains within the MS 300.

- The receiver chain, as known in the art, includes
- 5 scanning receiver front-end circuitry 306 (effectively providing reception, filtering and intermediate or base-band frequency conversion). The scanning front-end circuit is serially coupled to a signal processing function 308.

10

An output from the signal processing function is provided to a suitable output device 310, such as a screen or flat panel display.

- 15 The receiver chain also includes received signal strength indicator (RSSI) circuitry 312, which in turn is coupled to a controller 314 for maintaining overall subscriber unit control. The controller 314 is also coupled to the scanning receiver front-end circuitry 306 and the signal
- 20 processing function 308 (generally realised by a DSP).

- The controller 314 may therefore receive bit error rate (BER) or frame error rate (FER) data from recovered information. The controller is also coupled to a memory
- 25 device 316 that stores operating regimes, such as decoding/encoding functions, synchronisation patterns, code sequences and the like.

- In accordance with the preferred embodiment of the
- 30 invention, the memory device 316 stores data relating to neighbouring cell sites or systems. Furthermore, a timer

318 is operably coupled to the controller 314 to control the timing of operations (transmission or reception of time-dependent signals) within the MS 300, particularly in regard to compressed FDD mode, TDD mode and, for 5 example, GSM TDMA timing.

As regards the transmit chain, this essentially includes an input device 320, such as a keypad, coupled in series through transmitter/modulation circuitry 322 and a power 10 amplifier 324 to the antenna 302. The transmitter/modulation circuitry 322 and the power amplifier 324 are operationally responsive to the controller.

15 Of course, the various components within the MS 300 can be realised in discrete or integrated component form, with an ultimate structure therefore being merely an arbitrary selection.

20 In accordance with the preferred embodiment of the invention, scanning receiver front-end circuitry 306, the transmitter/modulation circuitry 322 and power amplifier 324, under the control and guidance of the signal processing function 308, memory device 316, timer 25 function 318 and controller 314 have been adapted to receive and/or transmit to the infrastructure in compressed FDD mode. This is performed in response to instruction from the infrastructure to enter such a mode, or as a self-initiated function decided by the controller 30 314 in response to a recognition of the MSs operating conditions.

On entering such a mode, the subscriber unit 300 switches to a scanning mode of operation to receive and decode signal transmissions from neighbouring cells or systems,  
5 before returning either to FDD compressed mode, or to the normal FDD mode.

It should be noted that there are three possibilities to create an idle period within a FDD frame through  
10 compressed mode:

- 1) at the beginning of the frame;
- 2) in the middle of the frame (as shown in FIG. 1); and
- 3) at the end of the frame

15 Thus, in the third case, for example, a MS would switch directly from the compressed mode into the next frame which would be into the normal FDD operational mode. It is within the contemplation of the invention that two consecutive frames, combining the end of one frame (3), with the beginning of the next frame (1) to obtain a larger idle period. In this case, a MS also moves directly from the compressed mode to the normal mode.  
20

25 In the preferred embodiment of the invention, this scanning operation is used to acquire synchronisation with alternative cells or systems, such as acquiring the TDD synchronisation parameters, in order to detect, say, further GSM FCCH and GSM SCH.

If it is determined that a hand-over operation is required, then the MS 300, using the aforementioned elements, switches into a TDD mode of operation, then uses the acquired synchronisation parameters (from TDD mode) of GSM FCCH and SCH, prior to handing over to the alternative GSM system.

To explain the inventive concepts of the present invention in more detail, and in particular the benefits of the invention, let us first consider the example of FDD to GSM handover. Handover from UTRA to GSM is more efficient for voice or low bit-rate data applications. This is due to only one code for FDD and TDD, one timeslot in uplink and downlink for TDD and one slot in GSM being required to perform the full hand-over process.

It is noteworthy that, if the service is voice, it is better to perform hand-over as soon as possible. It is also noteworthy that if voice traffic is handed off from UMTS to GSM, while the MS is in TDD mode, the MS has 13 slots available each frame (one slot of the 15 time slots constituting a frame is dedicated to transmission, and another to reception) to make measurements without needing to transfer to compressed mode.

Higher data rate services may apply if the GSM communication system actually includes the global packet radio system (GPRS) or the high-speed circuit switched data (HSCSD) system. This may affect more non-real-time applications that may tolerate a longer transfer delay.

In accordance with a preferred embodiment of the invention, the time needed to execute measurements can be quantified. Handover to GSM requires accessing the GSM  
5 Broadcast Control CHannel (BCCH) and perform power measurements, once per GSM frame (i.e. every 4.615 msec's).

The sample period is at most 200 msec's to achieve the  
10 accuracy required by the GSM standard, as defined in GSM 05.08. The time needed to perform a signal quality measurement is 1.2 msec. As several BCCHs have to be measured, this step is typically longer: for 2 BCCH measurements 1.9 msec's are needed while for 3 BCCH  
15 measurements 2.6 msec's are needed.

Detection of GSM Frequency Correction CHannel (FCCH) and Synchronisation CHannel (SCH) channels is a pre-requisite for standards compliance. FCCH bursts necessary for  
20 synchronisation is slot "0" of frame -0, -10, -20, -30 and -40. More specifically, the time difference between two FCCH bursts is either 10 GSM frames (for frames 0 to 40) or 11 GSM frames (for frame-40 to frame-0 of the next GSM multiframe), if the timing is such that it is between  
25 frame -40 and the beginning of the next frame. The SCH burst follows exactly one frame after FCCH. Both channels have to be decoded at least once every 10 seconds for each neighbouring cell.

Referring now to FIG. 4, a timing diagram 400 of a GSM synchronisation channel (SCH) is shown, as used in accordance with a preferred embodiment of the present invention.

5

FIG. 4 also shows the detection of a GSM FCCH when a MS is operating in a UMTS FDD mode. The GSM super-frame structure 402 consists of 26 GSM frames (FGSM) 404 and lasts 120 msec's. The structure is comparable with the 10 UMTS super-frame (SFUMTS) 406 that lasts 120 msec's as well. A GSM multi-frame (MFGSM) 408 consists of 51 GSM frames 410.

Both FCCH 412 and SCH 414 are transmitted on the first 15 slot of their corresponding GSM frames (frames carrying FCCH and SCH are consecutive). Five FCCH/SCH pairs are scheduled during a FCCH/SCH multi-frame structure and FCCH is scheduled at frame numbers -0, -10, -20, -30 and -40.

20

As seen in FIG. 4, every two GSM super-frames 402, comprises 52 GSM frames 404 (equivalent to two UMTS super-frames 406). A UMTS idle measurement period 418 created regularly once every UMTS super-frame (generated 25 by interrupting data transmission through compressed mode, for example) is offset by one frame 416 with respect to the GSM FCCH/SCH multi-frame structure (51 GSM frames). This means that if the idle period created in a UMTS transmission is larger than a GSM frame duration 30 (4.615 msec's), at each super-frame a shift of one frame 416 is achieved.

Basically, in utilising a one-frame shift 416 per super-frame, in order to scan the whole multi-frame (to visit each frame of the multi-frame) there needs to be 51 shifts, and therefore 51 GSM super-frames. As there are 5 FCCHs in the FCCH/SCH multi-frame structure, at least one FCCH will be detected before 11 by 26 GSM frames, or 11 UMTS (or GSM) super-frames ( $11 \times 120 \text{ msec's} = 1.32 \text{ sec}$ ). This results from the worst-case distance between two consecutive FCCH, which is 11 frames. As explained earlier, at each GSM super-frame (26 GSM frames) it is possible to shift by one frame the positioning between UMTS (whose super-frame duration is equal to GSM super-frame duration). Thus the worst-case to get the FCCH is 11 GSM/UMTS super-frames.

In accordance with a preferred embodiment of the invention, two distinct phases are proposed. The first step is to transition from a FDD mode of operation to a TDD mode of operation in order to scan and/or receive signal transmissions from neighbouring cells or systems. The second, subsequent phase is to transition (hand-over) from a TDD mode of operation to an alternative communication system such as GSM.

For the first phase of FDD to TDD hand-over, it is noteworthy that two synchronisation slots exist per TDD frame, one situated in the middle of the frame and the second in the second half of the frame. A 5 msec idle

period in FDD downlink transmission is enough to acquire synchronisation from FDD to TDD.

In summary, a frame lasts 10 msec with two SCHs. That  
5 means with two SCHs mapped onto two separate time slots  
(duration of a slot 10/15 msec), the time between two  
consecutive SCHs is less than 5 msec. Hence, with a 5  
msec sliding window one can capture either the first SCH  
or the second SCH in a frame.

10

FIG. 5 displays a timing diagram 500 of transmissions in  
a UMTS TDD mode. Basically, the transmission is carried  
out in a slot 502, in each frame 504 that has been  
15 previously reserved. Multiple transmissions from  
different MSs are possible within the same time slot.

Referring now to FIG. 6, a timing diagram 600 of a TDD  
20 Synchronisation CHannel (SCH) for TDD detection from a  
FDD mode of operation 602 is shown, in accordance with a  
preferred embodiment of the present invention. In  
particular, FIG. 6 shows how, by creating and using at  
least a 5 msec silence period 606 through compressed mode  
25 in one 10 msec FDD frame 604, the TDD SCH is detected.

It is noteworthy that if only one synchronisation channel  
(SCH) is transmitted per TDD frame, two compressed frames  
- the first at the end of first frame and the second one  
30 at the beginning of the second frame - are sufficient

enough for a MS to capture the synchronisation information on the TDD synchronisation channel.

However, as shown in FIG. 6, if two SCHs slots 620 are  
5 transmitted during each TDD frame 622, then only one FDD frame needs to be used in a compressed mode in order to obtain synchronisation with the TDD system.

- Such a fast transition from FDD operation to TDD  
10 operation can be supported by a dual mode MS, which is particularly advantageous in the context of a Software Definable Radio, where both modes will use the same 10 msec frame and can perform measurements in each mode.
- 15 Advantageously, as the TDD cells within the coverage area are frame-synchronized, the downlink/uplink timing obtained for a single TDD cell will also be valid for other cells belonging to the same network in the same coverage area.
- 20 For both modes it is expected that the UMTS standard will ultimately specify that the UTRA RNC will indicate the channel numbers used for the FDD and TDD cells in the coverage area, as well as the RNC spreading/scrambling  
25 codes used. This will significantly reduce the time required in the synchronisation procedure, since knowing the scrambling code, the super-frame synchronisation may be easily acquired and the system cell specific BCCH information read.

The second phase of the process, if circumstances in measurements performed during the first phase dictate, is a hand-over from a TDD mode of operation to operating on another system such as GSM. To optimise any UMTS hand-

5 over procedure it is useful to discriminate between:

- (i) real-time (RT) and
- (ii) non-real-time (NRT) bearer services,

as well as between:

- (iii) low data-rate (LDR) and

10 (iv) high data-rate (HDR) service provision,  
due to the different requirements in each scenario.

15 (i) Real-time services have stringent delay requirements. However, they have much more relaxed bit-error rate (BER) requirements. Since a UMTS hand-over shall be seamless, i.e. not noticeable to the user, the hand-over procedure should not cause additional delay.

20 (ii) In contrast, non-real-time (NRT) services have very low delay requirements. However, they do include stringent BER requirements. This implies hand-over of NRT services shall be loss-less, i.e. no data loss at the expense of a possible delay increase.

25 (iii) Only a few time slots are busy and idle slots may be naturally used for monitoring purposes in a LDR scenario. This is the case in a simple voice communication, where only two time slots per frame are used, one for uplink and one for downlink. In this  
30 scenario, the time to acquire the FCCH (synchronisation time) was found to be at most 235 ms (see UTRA Handover

UMTS XX.15 v1.0.0 1999-02), assuming that all idle slots are devoted to the tracking of a FCCH burst, meaning that no power measurements are done concurrently.

- 5    The FCCH is supposed to be perfectly detected meaning that the FCCH is detected if it is wholly found to be present in the monitoring window. Once the FCCH is detected, the SCH location is also known. Hence, in this scenario, using the idle slots is a valid and natural  
10   option. Indeed, this is the preferred technique to perform measurements in TDD mode of operation if only GSM cells are monitored, where other solutions such as slotted frames or dual receiver for low data traffic are removed.

- 15   Referring now to FIG. 7, an example 700 of the distribution of a MS operating in a FCCH GSM slot and in a TDD slot is shown, in accordance with a preferred embodiment of the present invention. In particular, FIG.  
20   7 shows the matching between TDD and GSM frames when FCCH detection is performed.

- Two concentric circles are shown, one representing a FCCH GSM slot 702, and one representing a TDD slot 704. The  
25   example shows TDD and GSM alignment where only three idle TDD slots (slots '0', '1' and '2') 706-710 are available for monitoring. This is because three continuous TDD slots are needed to be sure to detect the FCCH GSM as described in TSG/RAN/WG1/TS26.212 v2.2.0 (TSGR1#7(99)e18  
30   - "Multiplexing and Channel Coding (FDD)", source Third Generation Partnership Project (3GPP) .

Depending on the relative positions different searching times are obtained. The detection is achieved when the entire FCCH falls in a TDD slot. The maximum  
5 synchronisation time is however limited to 235 ms for voice transmission, where up to 13 slots are available.

(iv) A monitoring period of at least three slots is also desirable whilst in a high data-rate service  
10 provision mode. The number of consecutive time-slots (TSs) needed to obtain an effective monitoring period of three TSs depends on the frequency synthesiser characteristics. When it is impossible to free the number of slots needed for effective monitoring, the data  
15 rate can be slightly reduced for the duration of the monitoring.

This is acceptable as the data rate needs to be adapted to the available resource in GSM before the handover can  
20 be performed. The maximum time needed for detecting GSM FCCH in HDR case is bounded to 660 msec, as described in TSGR1 #3(99) 167, "Monitoring for handover from TDD to GSM" authored by Siemens and submitted to ETSI.

25

In a further embodiment of the present invention, GSM monitoring enhancement can be employed. The timing information of a GSM system, obtained by a MS that has acquired pre-synchronisation during GSM monitoring, may  
30 broadcast to other mobiles via the UMTS RNC. A yet further possibility to speed up GSM monitoring is to

perform monitoring on several GSM frequencies in parallel.

Clearly, a person skilled in the art would recognise that  
5 the aforementioned inventive concepts are applicable to any tri-mode MS, for example FDD (UMTS)/TDD (UMTS)/GSM. It is very likely the manufacturers will design UMTS MS to cover both FDD and TDD modes, if TDD is adopted and spectrum is provided.

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It is within the contemplation of the invention that in medium-heavy loaded conditions, the interference is a very constraining factor and the utilization of compressed mode will need to be limited as much as  
15 possible. In contrast, in lightly-loaded traffic conditions the interference is not an issue. Hence, if there are no constraints in time dedicated for measurements, the compressed mode may be used as specified in the standard.

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Furthermore, TDD may be seen as an escape mode due to its time-slotted structure that makes the use of compressed mode unnecessary. MSs operating in FDD mode may switch to TDD, as the time needed is short, perform measurements  
25 (inter-frequency measurements to switch to other technologies or to simply measure radio signal quality on other technologies) and then go back into FDD mode.

Depending on the control algorithm, this procedure may be  
30 applied from a critical traffic load and is preferably a network decision.

Although the preferred embodiment of the invention has been described with reference to hand-over to a GSM communication system, it is within the contemplation of the present invention that hand-over to any form of communication system could be achieved, as long as the parameters of such a communication system are obtained during a TDD mode of operation. For example, when low data rate services are being used, only one code for FDD and TDD, one timeslot in uplink and downlink for TDD and one slot in GSM is required to perform hand-over of the communication. In contrast, when high data rate services are being used, only one code for FDD and TDD, one timeslot in uplink and downlink for TDD and a plurality of slots in say, a GPRS or an Edge communication system is required to perform hand-over of the communication.

It will be understood that the communication system, communication unit and method of operation described above provides the following advantages:

- (i) Measurements and synchronisation from UMTS-FDD mode to other frequencies or systems are quickly accomplished;
- (ii) By performing measurements through a TDD mode rather than through "compressed mode" in joint FDD and TDD systems avoids or at least reduces the utilisation of compressed mode to perform measurements and acquire synchronisation on other frequencies/systems.

- (iii) Reduces the additional interference that would have been created by the utilization of compressed mode.
- (iv) The synchronisation time on FCCH of GSM is reduced 5 by using TDD mode in joint FDD-TDD systems, for example for a voice service in FDD to GSM: synch time cost = 1.32sec, whereas for FDD to TDD to say, GSM: synch time cost = 240 msec.
- 10 (v) Faster handover process for UMTS-FDD to other non UMTS systems (e.g. GSM, GPRS, EDGE, HSCSD, IS-95, IS-136, private networks, TETRA, DECT, etc.) by proceeding with a double hop handover FDD to TDD to a non- UMTS system operation and making measurements in TDD.
- 15 (vi) The application to Software Definable Radio (SDR) is particularly advantageous as MS will be re-configurable. The proposed solution can be completely applied to perform measurements for flexible spectrum sharing 20 purposes in SDR context.

Thus, a communication system, a communication unit, a method of monitoring signal transmissions and a method of 25 hand-over of a communication have been provided wherein the abovementioned disadvantages have been substantially alleviated.

**Claims**

1. A communication system comprising a first serving communication unit capable of communicating with a plurality of mobile stations in at least two operating modes, wherein the serving communication unit communicates with at least one of the plurality of mobile stations in a first frequency division duplex mode of operation, and the communication system being characterised in that the at least one of the plurality of mobile stations switches to a second time division duplex mode of operation to monitor a signal transmission from a second serving communication unit or second communication system.
- 15 2. The communication system according to claim 1, further characterised by the mobile station performing a hand-over operation from the time division duplex mode of operation to communicate with the second serving communication unit or second communication system.
- 20 3. The communication system according to claim 2, wherein the mobile station initiates the hand-over operation.
- 25 4. The communication system according to claim 2, wherein the serving communication unit initiates the hand-over operation.

5. The communication system according to any one of preceding claims 2 to 4, further characterised by the handover being performed from a UMTS frequency division duplex mode to a GSM communication system for voice or  
5 low bit-rate data applications.
6. The communication system according to claim 5, further characterised in that for low data rate services only one code for FDD and TDD, one timeslot in uplink and  
10 downlink for TDD and one slot in GSM is required to perform hand-over of the communication.
7. The communication system according to claim 5, further characterised in that for high data rate services  
15 only one code for FDD and TDD, one timeslot in uplink and downlink for TDD and a plurality of slots in a GPRS or an Edge communication system is required to perform hand-over of the communication.
- 20 8. The communication system according to any one of the preceding claims, further characterised by the communication system being a code division multiple access communication system and the mobile station switching into a compressed mode from the frequency  
25 division duplex mode in order to obtain at least one synchronising parameter of the time division duplex mode before switching to said time division duplex mode of operation.
- 30 9. A communication unit adapted to operate in the communication system of any one of the preceding claims.

10. A method of monitoring signal transmissions in a wireless communication system comprising a first serving communication unit capable of communicating with a plurality of mobile stations in at least two operating modes, the method comprising the steps of:

communicating between the serving communication unit and at least one of the plurality of mobile stations in a first frequency division duplex mode of operation; the method characterised by the steps of:

10 switching communication between the serving communication unit and the at least one of the plurality of mobile stations to a second time division duplex mode of operation; and

15 monitoring a signal transmission from a second serving communication unit or second communication system in said second time division duplex mode of operation.

11. A method of hand-over of a communication, comprising the steps of monitoring signal transmissions in a wireless communication system according to claim 10, the method further characterised by the step of performing a hand-over operation from the time division duplex mode of operation for the mobile station to communicate with the second serving communication unit or 25 second communication system.

12. The method of monitoring signal transmissions in a wireless communication system according to claim 10 or claim 11, wherein the communication system is a code division multiple access communication system and the  
5 method is further characterised by the step of:

switching the mobile station into a compressed mode from the frequency division duplex mode;

obtaining at least one synchronising parameter of the time division duplex mode; and

10 switching to said time division duplex mode of operation.

13. A communication system substantially as hereinbefore described with reference to, and/or as  
15 illustrated by, FIG. 2 of the accompanying drawings.

14. A communication unit substantially as hereinbefore described with reference to, and/or as illustrated by,  
FIG. 3 of the accompanying drawings.



Application No: GB 0030407.1  
Claims searched: All

Examiner: Gareth Griffiths  
Date of search: 17 August 2001

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**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H4L (LEP, LRPML, LRPMS, LRPMW)

Int Cl (Ed.7): H04B 7/26, H04Q 7/32, H04Q 7/38

Other: Online Databases: WPI, EPODOC, JAPIO, INSPEC

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	GB2336071 A (PHILIPS)	

- |   |  |
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| X Document indicating lack of novelty or inventive step   | A Document indicating technological background and/or state of the art.  |
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